Radioactive Materials Groundwater Protection Program Proposal

Clean Harbors Deer Trail, LLC

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CleanHarbors®
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Company

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Executive Summary

Clean Harbors Deer Trail, LLC (the site) first began accepting waste in 1991, and began monitoring for background groundwater radiochemical parameters in January of 1986. Since then, sufficient data has been produced to justify a thorough evaluation of the methods employed in the site's Groundwater Protection Program. This evaluation has been conducted based on the data collected and previous reports prepared regarding site conditions. The results of this evaluation indicate the potential for modifications to three major components of the site Groundwater Protection Program: 1) Monitoring Well Network, 2) Monitoring Frequency, and 3) Statistical Methods. Potential modifications to the monitoring well network have been evaluated based on the likelihood of facility wells to detect a release from a secure cell and the quality of data produced by samples from specific facility wells. Assessment of these criteria included gradient relationships between monitoring wells and secure cells, and percent saturation statistics for the screened interval of monitoring wells. Three monitoring zones, which are not part of the regulatory required detection monitoring network (as defined in 6 CCR 1007-3, Subpart F, Part 264), have been identified as stratigraphically higher than the regulated leachate level in the secure cells, and are not subject to impact from a release from the secure cells due to the downward groundwater gradients at the site. These zones are the Level 3, Level 4A and Level 6 zones. Thirty-four wells from the Level 4 zone have been identified as intermittently saturated, and therefore produce unreliable datasets for statistical analyses. Potential modifications to the monitoring frequency at the site have been evaluated based on migration potential and the necessity of sample independence. Groundwater flow rates at the site are not expected to exceed 4.0 feet per year. Due to these low flow rates, quarterly sampling is not necessary for early detection of a release. Also due to these low flow rates, quarterly sampling produces consecutive samples which are not independent, and are inappropriate for statistical analyses. Statistical methods have been evaluated based on the ability to minimize the frequency of false positives while maintaining sensitivity to increases in parameter concentrations. The low flow rates at the site and lack of a well defined groundwater gradient render an intrawell approach ideal for sample analysis at the site. A Shewhart-CUSUM approach, coupled with descriptive statistics, has been prescribed to meet these needs.

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1 INTRODUCTION

The Radioactive Materials Groundwater Protection Program Proposal presented here is being submitted by Clean Harbors Deer Trail, LLC (CHDT), a Clean Harbors Company, for the Clean Harbors property located at 108555 E. U.S. Highway 36 in Deer Trail, Colorado (the site, the facility). The facility is currently designated as a Regional Facility pursuant to the Rocky Mountain Low-Level Radioactive Waste Compact (99 Stat. 1902-1909, 42 USC 2121d). CHDT accepts only Naturally Occurring Radioactive Materials (NORM) and Technically Enhanced Naturally Occurring Radioactive Materials (TENORM). The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division, Radiation Program oversees activities relating to NORM/TENORM for the site.

This proposal will present suggested modifications to the radioactive materials component of the current Groundwater Protection Program, the basis for these modifications, and an introduction to the hydrology local to the site. The proposed modifications are based on data collected and reports written over the last 23 years. Radiochemical data collected includes over nine-thousand-seven-hundred analyses of twenty-three unique radiochemical species, beginning with the first radiochemical analyses conducted at the site in January of 1986. Hydrological data collected includes over seven-thousand groundwater level measurements at one-hundred-twenty-seven site wells, beginning with the first groundwater level measurement conducted at the site in January of 1986. Reports reviewed are all referenced in the Radioactive Materials License Application (2005) (see list of references in Section 5: *References*). The hydrology section of this report has been adapted from Section 2.4 of the Radioactive Materials License Application.

2 PROPOSED MODIFICATIONS

Proposed modifications to the current monitoring program have been designed to optimize the sampling and analysis process for efficiency and maximization of data quality. Modifications to three program categories are being proposed. These categories are: 1) Monitoring Well Network, 2) Monitoring Frequency, and 3) Statistical Methods. The Groundwater Sampling Standard Operating Procedure document has been updated to reflect the proposed changes, and is included with this report as Appendix A: *Groundwater Sampling for Radioactive Materials 15.OPS.16*.

2.1 Monitoring Well Network

A reduction in the monitoring program is suggested regarding the number of detection monitoring wells, with no change to the number of inspection monitoring wells. It is suggested that detection monitoring in the Level 4 zone be reduced to only include wells that have historically contained water in over 75.0 percent of the inspections. Monitoring zones that are hydrostratigraphically above the secure cell leachate should not be included in the detection monitoring program. These zones are the Level 3, Level 4A and Level 6 zones. The wells which will be included in the detection monitoring program are summarized in Table 1: *Inspection and Detection Monitoring Well Network* (presented on the following page).

2.2 Monitoring Frequency

It is suggested that the monitoring frequency of facility wells is updated from quarterly to semiannually. It is also suggested that sampling of Secure Cell Leachate Collection and Detection System sumps and the Secure Cell Permanent Sump occur annually.

2.3 Statistical Methods

A unique statistical methods program for the radioactive materials monitoring at the site has been developed to provide for early detection of release from a secure cell. Based on a combined Shewhart-CUSUM approach, the program is sensitive to both gradual increases and spikes in monitored parameter values. The proposed analysis program will minimize the frequency of false positives and provide for a robust approach for early detection of a release. Appendix B: *Statistical Methods: Radioactive Materials Monitoring* describes this program in detail.

TABLE 1
INSPECTION AND DETECTION WELL MONITORING NETWORK

Monitoring Zone	Well	Detection Monitoring[1]	Monitoring Zone	Well	Detection Monitoring[1]	Monitoring Zone	Well	Detection Monitoring[1]
Level 3	L3-10		Level 4	L4-1		Level 4	L4-4	
	L3-11			L4-10			L4-40	
	L3-12			L4-11			L4-41	Yes
	L3-13			L4-12			L4-42	Yes
	L3-15			L4-13			L4-43	
	L3-16			L4-14			L4-44	
	L3-17			L4-16	Yes		L4-45	
	L3-19			L4-17			L4-46	
	L3-2			L4-18			L4-5	
	L3-22			L4-19			L4-6	
	L3-24			L4-2			L4-8	Yes
	L3-25			L4-20			L4-8N	Yes
	L3-26			L4-21			L4-9	Yes
	L3-27			L4-22			L4-9N	Yes
	L3-28			L4-23			L4-9S	Yes
	L3-29			L4-24			L4-9W	Yes
	L3-3			L4-25		Level 4A	L4-32A	
	L3-30			L4-26	Yes		L4-32EA	
	L3-31			L4-27			L4-32WA	
	L3-32			L4-28	Yes		L4-33A	
	L3-33			L4-29	Yes		L4-33EA	
	L3-34			L4-3			L4-33WA	
	L3-35			L4-30	Yes		L4-7A	
	L3-36			L4-31	Yes	Level 5	L5-10A	Yes
	L3-37			L4-32	Yes		L5-3	Yes
	L3-38			L4-32E	Yes		L5-4	Yes
	L3-39			L4-32W	Yes		L5-5	Yes
	L3-40			L4-33	Yes		L5-6	Yes
	L3-41			L4-33E			L5-7	Yes
	L3-42			L4-33W	Yes		L5-8	Yes
	L3-43			L4-34			L5-9	Yes
	L3-44			L4-34E		Level 6	L6-1	
	L3-46			L4-34W	Yes		L6-2	
	L3-47			L4-35			L6-3A	
	L3-6			L4-36				
	L3-7			L4-37				
	L3-8			L4-38				
	L3-9			L4-39				

1 All wells in this list are Inspection Monitoring Wells. All wells designated with “Yes” under “Detection Monitoring” are Detection Monitoring Wells.

3 JUSTIFICATION FOR PROPOSED MODIFICATIONS

3.1 MONITORING WELL NETWORK

The proposed monitoring program is designed to optimize the detection of a release while minimizing the frequency of false positives and procedural excess. One method employed to minimize the frequency of false positives includes eliminating the monitoring of wells that are not expected to be subject to contaminated groundwater in the event that a release occurs. Another method is to eliminate the monitoring of wells where the groundwater samples collected do not represent the quality of groundwater passing those well points. These methods of minimizing false positives also serve to reduce procedural excess in the monitoring program.

Wells that are intermittently saturated do not provide samples that accurately represent the quality of groundwater passing those well points. The zone of intermittent saturation contains groundwater which is regularly passing through previously dry soil media and filling up the dry well. This introduction of saturated conditions to previously unsaturated media results in chemical reactions between the unsaturated soil media, soil gas, and groundwater. These reactions render the chemistry of the groundwater in the intermittently saturated zone different from the chemistry of the groundwater passing the well point. Samples from wells screened in this zone will provide inconsistent results that do not depict representative trends in the groundwater passing the well point. Therefore, these wells should be removed from the detection monitoring program. From the Level 4 wells, there are twenty wells which are saturated more than 75.0 percent of the time, and would remain in the program. All of the Level 5 wells are consistently saturated and will remain in the detection monitoring program.

Wells that are screened in zones hydrostratigraphically higher than the regulated leachate level in the Secure Cells will not detect the event of a release. This is due to the fact that the vertical groundwater flow direction on the site is downward. The direction of flow on the site is explained in detail in Section 4.2.5: Hydraulic Characteristics. Because these wells will not detect a release, it is suggested that these wells be removed from the detection monitoring program. This action will serve to both reduce the risk of false positive and reduce procedural excess in the monitoring program. Monitoring zones which are hydrostratigraphically higher than the secure cell leachate level are the Level 3, Level 4A and Level 6 zones. A list of all wells proposed as detection monitoring and inspection monitoring is included in Table 1: *Inspection and Detection Monitoring Well Network*. Please note that all current program wells will remain inspection monitoring wells.

3.2 Monitoring Frequency

As discussed in the Hydrology section of this document, the maximum estimated average linear groundwater flow velocities for the facility are approximately 4.0 feet per year. Due to the low velocity of groundwater flow at the facility, quarterly sampling is not necessary to provide for timely detection of a release at the facility. Therefore, it is suggested that the monitoring frequency at the facility wells be reduced to semiannually. Additionally, at some well locations, the quarterly sampling frequency may not allow enough time for recovery, creating a situation where the subsequent samples do not represent independent groundwater sources, as required by 6 CCR 1007-3 §264.97. This is evident at the location of the well cluster around well L4-9, where there is a noticeable depression in the groundwater table due to slow recovery rates. In this example, the water table still has not fully recovered after three months following sampling of the wells.

Analysis at the Secure Cell Leachate Collection and Detection System sumps and Secure Cell Permanent Sumps is intended to characterize the leachate, or detect the present of leachate outside of the primary liner, and is not intended to provide a background dataset for statistical comparisons like that for groundwater. Therefore, annual sampling is sufficient to characterize the fluids in these sumps.

3.3 Statistical Methods

A combined Shewhart-CUSUM control chart approach to statistical analysis has been suggested for radioactive materials monitoring at the site. This approach is sensitive to detection of both gradual increases in parameter concentrations as well as spikes in parameter concentrations. This approach also serves to reduce the frequency of false positives as additional samples are added to the background database. Additionally, descriptive statistics will be generated for each dataset relating the measures of central tendency, dispersion and distribution. Below is a brief description of the control chart method intended for the site. Appendix B: *Statistical Methods: Radioactive Materials Monitoring* describes the proposed statistical analysis methods in more detail.

The proposed control chart analysis has been performed on the available datasets at the site (please see Appendix C: *Control Charts*). A control chart "failure" occurs when the plotted Shewhart or CUSUM value exceeds its respective limit. The total combined Shewhart-CUSUM failure rate for all available monitoring well data is 2.4 percent. This failure rate is well within the maximum expected failure rate (approximately 5.0 percent) of a stable system for the control limits specified (see Appendix B for details about control limits). Of the ten datasets that contain historic Shewhart-CUSUM failures, seven fail only in the first control period. (A control period corresponds to a period of comparisons in which the background database has not been updated. The control limits improve in calibration with each successive control period. In the proposed statistical methods approach, the control period has duration of two years, as described in Appendix B). Of the other three datasets, two datasets (Radium-228 and Radium-226 at well L5-5) fail due to poorly calibrated limits based on inconsistencies in the sampling history. These inconsistencies are evident upon inspection of these dataset’s control charts. The final dataset, Radium-226 at well L5-10A, records a spike in the laboratory measured parameter concentration. While the range in the measured values is only 1.2 pCi/L, due to the tight control limits of the comparison, this spike has generated both a CUSUM and a Shewhart failure. The design of the control charts dictates that a CUSUM failure will continue to occur until the background dataset is updated (a new control period begins). By the time that this permit modification is implemented, the third control period for this dataset is expected to have begun. At this point the dataset will be considered to be relatively mature, with well calibrated control limits in place.

4 HYDROLOGY

The geology and surface and groundwater hydrology of the facility has been characterized on several occasions throughout the facility history (Tweto (1979), Fox (1984), Colorado GeoLogic (1986 and 1987), McCulley, Frick & Gilman, Inc. (1995, 1997)). Much of this previous characterization is available in the following volumes of this application. The following sections summarize the surface and groundwater hydrology of the site and region based on results of these earlier documents and continuing data collection from the groundwater monitoring programs.

4.1 SURFACE WATER HYDROLOGY

As noted, the site vicinity is characterized by broadly rolling topography. The surface slope of the facility ranges from flat to about 6.0 percent. Topographic relief in the site vicinity results from erosional drainages, such as Beaver Creek (east of the facility), and Wetzel Creek (on the west), and their tributaries, that are incised in the highly erodible clay-loam soils. The limited alluvial deposits associated with these drainages typically consist of discontinuous lenses of clayey sand, sandy clay, and silty clay. There are no perennial streams, rivers, or surface water impoundments (other than stock tanks/ponds) near the facility. The only use of surface water within a 6.0-mile radius of the facility is in small retention ponds for watering stock.

Because the facility is topographically above the surrounding land, little or no potential for drainage onto the site exists (i.e., there are no upstream drainage areas). Downstream drainage basins include the Wetzel and Beaver Creek drainages, which ultimately discharge to the South Platte River approximately 30.0 miles north of the facility.

Evaluation of the potential for precipitation-induced runoff from the facility calculated the average annual runoff from the 325.0-acre site, based on annual precipitation of 14.0 inches, to be approximately 13.0 million gallons. Variations from a dry year (8.0 inches annual precipitation) to a wet year (20.0 inches) produce annual runoff of less than 1.0 million gallons to about 57.0 million gallons, respectively. In addition, the drainage basins were assessed and a floodplain analysis was performed for the confluence of the Beaver and Wetzel Creek drainages. Results of that study, based on a 100-year flood depth of 22.0 feet above the average stream elevation at the confluence, indicate that the lowest part of the facility is at least 93.0 feet above the predicted floodplain elevation.

Due to the lack of perennial streams and shallow groundwater aquifers, groundwater/surface water interaction in the vicinity of the facility is limited. Because there are no perennial streams near the facility, few data regarding the quality of surface waters are available. One sample collected from a stock pond near the facility was reported to contain a total dissolved solids concentration of 385.0 milligrams per liter (CGS, 1986).

4.2 Groundwater Hydrology

Several reports pertaining to regional and local groundwater occurrence and flow were prepared for earlier RCRA permitting and operational activities related to the facility. Data from those reports has been used in conjunction with data from ongoing monitoring activities related to the facility to develop the conceptual model for groundwater hydrology at the facility.

4.2.1 Regional Groundwater Occurrence

The site sits on the eastern edge of the Denver Basin. The Denver Basin encompasses four principal aquifers that are present in five major formations. The Dawson Arkose contains the Dawson Aquifer, the Denver Formation contains the Denver Aquifer, the Arapahoe Formation contains the Arapahoe Aquifer, and the Fox Hills Sandstone of the lower sandstone of the Laramie Formation contain the Laramie-Fox Hills Aquifer. Below these aquifers lies over 4,000.0 feet of the Pierre Shale before the Dakota Sandstone is encountered. The Denver Basin aquifers are eroded away at the location of the site, with the nearest aquifer formation, the Laramie-Fox Hills, outcropping about ten miles to the west. To the east of the site lies the Ogallala aquifer, contained within the Ogallala formation. This formation outcrops approximately 20.0 miles to the east of the site. Recharge to the Denver Basin aquifers on a regional scale is dominantly in the topographically higher southern portion of the basin. The Ogallala aquifer recharge is dominantly through the direct infiltration of precipitation. The facility site, sitting over the Pierre shale, is hydraulically isolated from these aquifer formations.

4.2.2 Local Groundwater Occurrence and Flow

Groundwater occurrence in the vicinity of the site is based on information from exploratory and site characterization activities over the life of the facility, information from the Colorado State Engineer's Office, and the ongoing facility groundwater monitoring program. The existing or potential hydrostratigraphic units underlying the facility consistent with the nomenclature used for the current groundwater monitoring program.

Due to the unique geological setting in the vicinity of the facility, the underlying deposits are hydraulically isolated from the regional aquifers. Therefore, in a classical sense, there are no major groundwater "aquifers" in either unconsolidated surficial deposits or the underlying bedrock (the Pierre shale) in the vicinity of the site. Further, groundwater supply wells in the vicinity are limited; all potable water is trucked to the site.

The facility is generally underlain by 250.0 to 415.0 feet of unsaturated materials (through which the potential for infiltration is negligible) overlying the saturated zones within the Pierre shale. Beneath the Pierre shale, potential water-bearing zones underlying the facility are limited to the 'D' and 'J' sandstones of the Dakota group, which are approximately 5,000.0 feet below the ground surface at the site location. Both sandstones are primarily oil and gas production zones; the water quality is poor due to naturally occurring concentrations of total dissolved solids and hydrocarbons. No other identifiable water-bearing zones occur between the Dakota Group and the Pierre shale. Naturally occurring ground water does occur in discontinuous perched zones underlying the facility. These isolated saturated zones are the focus of the discussion in the following section.

In addition, disposal of produced water from an onsite oil well (the Jolly-Axtell #2) to a pond (referred to as the "brine pond") in the northern portion of the facility has resulted in the increased presence of shallow ground water beneath the facility. The direction of water flow in this zone is primarily downward, as is discussed below. In 1988, Triegel & Associates evaluated the relationship between the pond operation and groundwater quality with respect to RCRA groundwater monitoring requirements. The Jolly-Axtell well and another oil well inside the property boundary (Zexco-State #1-36), were plugged and abandoned in 1986 and 1984, respectively, in accordance with Colorado Oil and Gas Commission regulations. The brine pond was closed in 1986.

4.2.3 Identification of Hydrostratigraphic Units

Based on historical characterization activities at the facility and the current groundwater monitoring program, the hydrostratigraphic units underlying the facility have been classified in different zones as follows (McCulley, Frick, and Gilman, 1997):

- The Level 3 Zone (the sand lens occurring in the surficial silty clay unit);
- The Level 4A Zone (the interface between the surficial silty clay unit and the underlying weathered Pierre shale);
- The Level 4 Zone (the interface between the weathered Pierre shale and the unweathered Pierre shale);
- The Level 5 Zone (the uppermost saturated portion of the unweathered Pierre shale); and
- The Level 6 Zone (the first occurrence of saturated conditions in the alluvial drainages outside the compliance boundary).

Monitoring wells have been installed in these hydrostratigraphic zones to assess groundwater conditions and quality beneath the facility. The wells included in the facility monitoring program are labeled in accordance with the zone classification presented here (e.g., Level 3 Zone well numbers begin with Level 3). Eight Level 5 wells comprise the detection monitoring program for the facility and fulfill the groundwater monitoring requirements in 6 CCR 1007-3, Subpart F, Part 264 for permitted hazardous waste disposal facilities. The Level 3, Level 4A, Level 4, and Level 6 wells comprise the inspection monitoring program for the facility, and currently supplement the regulatory-required detection monitoring well network. Additional wells were installed in the Level 4 and Level 4A Zones as part of the RCRA Facility Investigation of the closed brine pond associated with the Jolly-Axtell #2 oil well. These wells, referred to as the BP wells, are inside and outside the northern compliance boundary. Water quality data from the BP wells has been used historically in establishing part of the historical water-quality database. These wells, however, are no longer included in the facility monitoring program.

The Level 3 Zone is defined as the discrete lenticular sand body (i.e., the Level 3 sand unit) that occurs infrequently in the surficial silty clay unit. Monitoring wells were historically installed at 50.0 foot intervals along the compliance boundary and in those areas where the Level 3 Zone is present. However, in a recent Class 2 Modification to the Part B Permit, the approach to the number and location of new Level 3 Zone wells was modified; new Level 3 wells are located along potential fluid migration pathways in the Level 3 Sand Unit. Level 3 wells are screened from approximately 9.0 to 36.0 feet below the ground surface, with water being detected in only one of the Level 3 wells throughout facility history. During the construction of future cells at the facility, a large part of the Level 3 Sand will be removed. In addition, the cell construction specifications require the removal of Level 3 Sand and replacement with an engineered clay barrier (minimum hydraulic conductivity of 1.0×10^{-8} cm/sec) of sufficient thickness to provide a 1,000-year travel time barrier to any migration of fluids from the secure cell to the remaining Level 3 Sand.

The Level 4A Zone is defined as the interface between the surficial silty clay unit and the underlying weathered Pierre shale. Monitoring wells are installed at 100.0-foot intervals in areas where the Level 4A Zone is (or historically was) saturated. Level 4A Zone wells are screened from approximately 12.0 to 19.0 feet below the ground surface. The saturated conditions requiring Level 4A wells occur only along the northern compliance boundary in the vicinity of a former oil field brine pond near well L4-33.

The Level 4 Zone is defined as the interface between the weathered Pierre shale and the underlying unweathered Pierre shale. Level 4 Zone wells are screened from approximately 32.0 to 64.0 feet below the ground surface. The typical depth of the weathered/unweathered shale contact is approximately coincident with the proposed depths of the landfill cells. Monitoring wells are installed at 300.0-foot intervals along the compliance boundary except in areas where the Level 4 Zone is (or historically was) saturated, where closer (approximately 100.0-foot) spacings are required.

The saturated conditions requiring tighter spacing occur only along portions of the northern compliance boundary in the vicinity of the former brine pond and along the western compliance boundary in the vicinity of Cells 1 and 2. Several Level 4 Zone wells have been installed inside the compliance boundary adjacent to Cells 1 and 2, and one Level 4 Zone well (Level 4-9W) is installed outside the compliance boundary west of Cell 2. The occurrence of saturated conditions adjacent to Cell 2 results from recharge of incident precipitation through the base of the Cell 2 excavation, which was unlined from about August 1989 to July 1995, prior to construction of the liner system.

Although standing rainwater and snowmelt were historically pumped from Cell 2, water remained in the excavation for several days prior to removal. During this time, water apparently seeped into the weathered portion of the Pierre shale that was exposed in the base and walls of the unlined excavation and slowly moved along the weathered/unweathered Pierre shale interface.

The Level 5 Zone represents the uppermost water-bearing unit at the facility and is defined as the uppermost saturated portion of the unweathered Pierre shale. Eight Level 5 Zone monitoring wells, installed along the compliance boundary, comprise the facility's groundwater detection monitoring network. The Level 5 wells are screened in the silt lenses that occur at various depths in the unweathered Pierre shale, ranging from approximately 250.0 to 415.0 feet below the ground surface.

The Level 6 Zone is defined as the first occurrence of saturated conditions in the alluvial drainages outside the compliance boundary. Focused recharge in offsite drainages results in limited areas of saturation that occur in shallow alluvial materials. Three Level 6 Zone wells are in the vicinity of the facility. The wells are screened in silt and fine sand units overlying the weathered Pierre shale, and in the unweathered Pierre shale. Depth to water in the Level 6 Zone wells ranges from approximately 10.0 to 50.0 feet below the ground surface.

4.2.4 Historic Water-Level Trends

The facility has conducted extensive groundwater monitoring around the current permitted area. Of the one-hundred-and-twenty-seven monitoring wells at the facility, water has never been detected in seventy of the wells, including all but one of the Level 3 wells. Groundwater elevations are showing a rising trend among the Level 4 and Level 4A wells, with stable water table elevations tracked in the Level 5 and Level 6 wells. The early water levels measured in Level 5 Zone wells were erratic, indicative of the slow recovery of the wells between quarterly sampling events. However, since 1992, due to a longer period between sampling events and the initiation of low-flow sampling techniques, the water levels appear to be more consistent than the earlier measurements indicate.

4.2.5 Hydraulic Characteristics

Discussion of hydraulic characteristics (i.e., groundwater flow direction and velocity) is somewhat misleading because it implies the presence of a conventional aquifer system, which is not the case for the facility. However, ground water does exist in discrete perched systems. The Level 5 zone, characterized by thin laminated beds of silt and clay, is likely recharged by fracture flow (McCulley, Frick, and Gilman,

1997) and flow through thin, silty partings. The Level 4A and Level 4 zones exhibit precipitation dominated recharge. Due to the significance of precipitation recharge to the Level 4 and Level 4A zones, surface drainage and runoff patterns are reflected in the location and elevation of groundwater in these zones.

The initial investigations conducted to complete the Part B Permit application thoroughly evaluated the hydraulic properties of current or potential hydrostratigraphic units in the vicinity of the facility. Testing included thirty *in situ* standpipe permeability tests, thirty-one packer tests, two pumping tests, and ten laboratory analyses on undisturbed and remolded samples.

In addition, thirty-four slug tests were performed in all wells at and near the facility in which static water levels were at or above the screened intervals (twenty-four Level 4 and Level 4A wells, eight Level 5 wells, and two Level 6 wells).

Based on results from these investigations, McCulley, Frick, and Gilman presented a summary of hydraulic conductivity values for the different hydrostratigraphic units. The saturated, horizontal hydraulic conductivity of the units underlying the facility varies from 5.1×10^{-4} to less than 8.6×10^{-8} cm/sec. The maximum estimated average linear groundwater flow velocities for the facility are approximately 4.0 feet per year. Because the extent of saturation in the Level 4 and Level 4A Zones is limited, and the Level 5 Zone wells yield so little water, the performance of long-term multiwell pumping tests at the facility has not been possible. Therefore, no estimates of formation storativity are available.

Depending on moisture content (sometimes less than 1/100,000 of the saturation value), flow velocities in the unsaturated portions of the Level 4A, Level 4, and Level 5 zones, which are generally more extensive than the areas of saturation, can be several orders of magnitude lower than saturated flow velocities (McCulley, Frick, and Gilman, 1997).

Because hydrogeologic conditions at the facility result in limited areas of saturation in shallow hydrostratigraphic zones and there is no definable hydraulic gradient in the Level 5 Zone, presentation of potentiometric surface maps to assess groundwater flow direction in each zone is not warranted. However, the following general statements can be made about groundwater flow beneath the facility:

- Of the one location at which groundwater has been detected in the Level 3 zone, well Level 3-42, flow is expected to be vertically downward at this location because groundwater here is perched in a depression at the base of the Level 3 Sand. In the event that saturated conditions were to occur above the critical elevation of this isolated depression, groundwater would travel down dip along the base of the Level 3 Sand.

- As indicated by the vertical head differences in adjacent wells completed in the upper Level 4A Zone and in the lower Level 4 Zone, the primary groundwater flow direction here is vertical, as the residual water in the surficial silty clay unit drains vertically into the underlying Pierre shale.

- The low hydraulic conductivity of the geologic units at the facility limits the amount of recharge to wells between sampling events. Lateral flow in the Level 4 Zone is predominantly the result of groundwater gradients imposed during the sampling process. As an example, the sampling frequencies at the quarter year interval have not allowed sufficient time for natural gradients to return, resulting in a local depression in the vicinity of the closely spaced Level 4 wells which have been consistently sampled west of Cell 2 (wells Level 4-9, Level 4-9S, Level 4-9N, Level 4-9W and Level 4-10).

- The Level 5 Zone represents the "uppermost aquifer" at the facility, as that term is used in the regulatory context (40 CFR §260.10). In a conventional hydrogeologic sense, the Level 5 Zone is not an aquifer, as evidenced by low yields to wells and very slow recovery rates following purging and sampling. Saturated zones monitored by the Level 5 Zone wells are hydraulically isolated silt lenses recharged by fracture flow.
- Ground water in the Level 6 Zone is assumed to flow horizontally along the offsite drainages, with a small amount of vertical leakage to the underlying geologic units.

4.2.6 Groundwater Chemistry, Quality, and Monitoring

The historical chemistry and quality of ground water underlying the facility were initially evaluated and historical water quality monitoring have occurred on a quarterly to annual basis since 1986. Groundwater quality data collected after the first acceptance of waste at the facility (i.e., after the fourth quarter 1991) are added to the historical database in accordance.

In general, the quality of ground water beneath the facility is poor (i.e., contains elevated concentrations of total dissolved solids [TDS]), primarily due to dissolution of evaporites and weathered components of the surficial silty clay unit and weathered Pierre shale, which affects water quality in the Level 4A and Level 4 Zones, and due to long residence times in the Level 5 Zone. In addition to elevated concentrations of TDS, concentrations of many inorganic parameters are naturally elevated. Mean concentrations of chloride, sulfate, fluoride, nitrate, selenium, and manganese are elevated in many of the wells at the facility, and often exceed drinking water and/or agricultural standards (McCulley, Frick, and Gilman 1997).

The various hydrostratigraphic units beneath the facility have distinct groundwater chemistries, which further indicates the lack of hydraulic connection between the limited areas of saturation in the Level 4A and Level 4 Zones and the unweathered Pierre shale (i.e., the Level 5 Zone). A marked increase in total dissolved solids from the Level 4A to the Level 4 Zone demonstrates both the relationship of the solid ground matrix dissolution to water chemistry, and the vertical nature of flow between these units.

Groundwater quality data from the monitoring wells at the facility are classified in six distinct groups for characterizing the composition of ground water and evaluating potential impacts from hypothetical releases from the secure cells. The well groupings were developed from an evaluation of hydrogeologic properties (depth to water, proximity to brine pond, etc.) and water chemistry data using standard geochemical techniques such as construction of bivariate plots of the major ions and trilinear diagrams, and evaluating the appropriateness of the well groupings using a multivariate statistical procedure referred to as a discriminant function analysis.

The well groupings appear to separate wells based on their position relative to the evolutionary flow path of the brine pond seepage. Groundwater becomes more concentrated in solutes as it moves laterally and vertically away from the brine pond through the subsurface, apparently as a result of the travel (i.e., residence) time in the subsurface geologic units and subsequent dissolution of the abundant evaporitic (gypsum, anhydrite, etc.) and other minerals (McCulley, Frick, and Gilman 1997). The shallow seepage waters lowest in TDS concentrations are from the wells near the brine pond. Although this seems counterintuitive, the brine pond liquids were actually very dilute, and the term “brine” is a misnomer. Results of chemical analyses on water samples collected from the former brine pond from January 1981 to February 1984 indicate that the oil-field water had an average TDS concentration of 1,879.0 milligrams per liter (mg/L), which is much lower than true brines (TDS concentrations greater than 100,000.0 mg/L). Only after the seepage migrates downward and away from the former brine pond does the water increase in TDS, through the dissolution of evaporite minerals along the flow paths, and take on the characteristics considered typical of saline waters (i.e., TDS greater than 10,000.0 mg/L). None of the ground water at the facility approaches the composition of a true brine.

Group 1 wells, which are the shallow Level 4A wells adjacent to the former brine pond along the northern compliance boundary, are the shallowest and screen the least geochemically “mature” shallow ground water at the Facility. Group 1 wells generally exhibit low concentrations of most major cations and anions. The wells in Groups 2 and 3, which monitor water quality in the dissipating brine pond seepage plume, are generally farther from the brine pond than Group 1 wells, or they are screened at greater depths. Group 4 wells produce the deepest of the “shallow” waters at the facility, and monitor water related, at least in part, to former oil-field activities. The wells in Group 4 that are along the western compliance boundary adjacent to Cell 2 are generally the deepest of the shallow wells and produce the most geochemically “mature” shallow water at the facility. The concentrations of most major cations and anions increase from the levels in Group 1 (and Group 6 wells, which are discussed below) to the concentrations exhibited by wells in Group 4.

Concentrations of major ions in Group 5 wells, the deep wells in the unweathered Pierre shale (i.e., Level 5), are generally quite different from the concentrations observed in shallower wells at the facility.

The concentrations of major anions and cations in Group 6 (Level 6) wells are relatively low and similar in many respects to Group 1 wells. Group 6 wells, which are in shallow geologic materials in surface water drainages outside the compliance boundary, are presumably subject to a greater recharge of dilute incident precipitation and shorter residence times than other wells at the facility. As a consequence, ground water in the Group 6 wells exhibits low concentrations of major ions.

4.2.7 Groundwater/Surface Water Interaction

As discussed above, surface water near the facility is limited to intermittent drainages that discharge to Wetzel and Beaver Creeks. Both creeks are ephemeral in the vicinity of the facility; the nearest perennial stream is about 30 miles away. Therefore, groundwater/surface water interaction is limited to (1) recharge to the limited alluvial deposits in the drainages following precipitation events, and (2) subsequent discharge from those deposits to surface waters. Based on water-level data provided by McCulley, Frick, and Gilman (1997) for the Level 6 wells, which show little, the significance of this interaction is limited. Thus, if groundwater/surface water interaction occurs, the occurrence time is less than the time between quarterly water-level monitoring events for the Level 6 wells.

4.2.8 Evaluation of Potential Releases to Ground Water

As discussed above, shallow groundwater resources are limited in the vicinity of the facility, and the hydraulic conductivity of the water-bearing zones (Level 4, Level 4A, and Level 5) is low. However, as part of the Ground Water Protection Plan, McCulley, Frick, and Gilman (1997) performed a worst-case assessment of a hypothetical release from a cell to the most permeable zone (Level 3), and subsequently to underlying saturated zones. This analysis was performed for the Level 3 Sand because this is the only hydrostratigraphic unit underlying the facility that could theoretically enable transport of a significant amount of fluid under saturated conditions. Cell design criteria and geologic/hydrogeologic factors that reduce the potential for a release to the Level 3 sand include:

- Cell construction specifications provide for the removal of a large portion of the Level 3 Sand, and isolation of the remainder with an engineered clay liner.
- The secondary liner components and sumps of the secure cells are approximately 20.0 to 40.0 feet below the elevation of the Level 3 and Level 4A Zones.
- The cells are designed such that the sloping liner components rapidly transmit leachate and other fluids to sumps so a leachate mound does not develop. As a result, the hydraulic head (driving force) is insufficient to cause leachate to leak laterally through the side-slope liner at an elevation equivalent to the Level 3 Zone (the Level 3 sand unit) or the Level 4A Zone (i.e., the interface between the silty clay unit and weathered Pierre shale).

These construction methods are designed to reduce/eliminate the potential for a release of leachate to the subsurface underlying and surrounding the facility. For leachate to accumulate and migrate through the liner system and out of a permanent sump to the subsurface, the following events would have to occur following placement of the final cover (McCulley, Frick, and Gilman 1997):

- The geocomposite drainage layer in the final cover (i.e., cap) would have to fail, allowing infiltrated water to pond on the underlying synthetic, 80.0-mil, geomembrane liner in the cap.
- Infiltration would have to occur through the synthetic liner in the cap, allowing the ponded water to seep into the underlying low-permeability clay liner in the cap.
- The low-permeability clay liner in the cap would have to absorb water until its moisture content increased to field capacity, allowing water to seep into the underlying wastes, which have been emplaced in accordance with Land Disposal Restrictions (LDRs) and waste treatment operations that are designed to restrict the amount and composition of leachate that can be generated.

- Leachate that percolates through the stabilized waste would enter the LCS, where it is monitored and removed. For a significant head to develop on the underlying liner system, the pump and monitoring system would have to fail.
- The leachate that collects in the nonfunctioning LCS would have to permeate through the primary liner system, which consists of an 80.0-mil liner and 3.0 feet of compacted clay with a permeability of less than 1.0×10^{-8} cm/sec.
- Any leachate that penetrates the primary liner would accumulate in the LDS sump, where it is monitored and removed. This system would have to fail as described above for the LCS sump for any significant seepage into the secondary liner system.
- The leachate would have to permeate the secondary clay liner system, which consists of an 80.0-mil liner and 3.0 feet of compacted clay with a permeability of less than 1.0×10^{-8} cm/sec.
- Leachate that penetrates the secondary liner system would accumulate in the permanent sump, which is also monitored.

Because of the secure cell construction and RCRA regulations pertaining to the routine monitoring and removal of fluids from the sumps of the secure cells, it is extremely unlikely that the release scenario described above could occur or go undetected.

4.2.9 Migration Pathway Analysis

It is evident from the previous section that the potential for a release from a secure cell at the facility is minimal. However, as part of the Ground Water Protection Plan, McCulley, Frick, and Gilman (1997) performed an analysis of potential migration pathways from a hypothetical release as follows.

In the extremely unlikely event of a release from the permanent sumps, which are approximately at the interface of the weathered and unweathered Pierre shale, leachate would enter the underlying geologic materials and migrate under unsaturated flow conditions. Fluids in the unsaturated zone are subject to capillary suction (i.e., surface tension forces between the water and the geologic materials) and gravitational forces. Since capillary force is proportional to pore size, the fine-grained materials, such as the weathered and unweathered Pierre shale, have higher capillary forces than coarser grained materials such as the Level 3 sand unit. As a result, unsaturated conditions (under capillary suction and gravitational forces) can cause fluids to migrate downward and locally laterally. Where a permanent sump is below the interface between the weathered and unweathered Pierre shale, fluids would migrate principally downward through fractures toward the Level 5 Zone wells. Due to the minute potential for a release from the secure cells, additional discussion (regarding dispersion, sorption, etc.) is not warranted.

4.2.10 Groundwater Use

As mentioned above, potable water for the facility is provided by trucks; there are no water- supply wells inside the facility boundary. In addition, nonpotable water for the facility is provided by collection and storage of noncontaminated surface water runoff during precipitation events. All water supply wells within a 6-mile radius of the facility are used for domestic, stock, or agricultural purposes.

A survey of registered wells within a 6.0-mile radius of the permit area was conducted in conjunction with the preparation of this application using records of the Colorado State Engineer. These records indicate the identification of three-hundred-and sixty-nine wells on the site and within a 6.0-mile radius.

More than half of the wells are on the site and within a 0.5-mile buffer zone. Most of these are used for groundwater monitoring. Of the wells used for water supply, most are in the Pierre shale bedrock, capturing small, discontinuous lenses of ground water in this otherwise relatively impermeable formation. A few of the shallower wells might capture limited alluvial ground water in the valleys of the larger intermittent streams in the area, such as Beaver and Wetzel Creeks.

Colorado's WellView Web System Water indicates three-hundred-and-seven active wells within a 6.0-mile radius of the facility, with depths ranging from 20.0 to 480.0 feet with a mean depth of 52.0 feet and a median depth of 40.0 feet. Yields of these wells range from 3.0 to 175.0 gallons per minute (gpm) with a mean of 15.6 gpm and a median of 10 gpm. Table 1 lists types of use for the water supply wells.

Table 2. *Types of Groundwater Use- Water Supply Wells.*

Type of Use	Number of Wells
Livestock	1000100
Domestic	32
Irrigation	2
Commercial	1
Other*	172

*One-hundred-and-sixty-eight of one-hundred-and-seventy-two wells designated as 'other' are monitoring wells.

5 REFERENCES

6 CCR 1007-3 §264.97. Code of Colorado Regulations, Colorado Public Health and Environment, Hazardous Materials and Waste Management Division: *HAZARDOUS WASTE - STANDARDS FOR OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE AND DISPOSAL FACILITIES.*

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